DARPA R&D Status Report

DARPA Order No.:

Program Code No.:

Contractor: General Electric Corporate Research and Development

Contract Amount: $2,582,405

Contract No.: N00014-96-C0145

Effective Date of Contract: June 26, 1996

Expiration of Contract: December 31, 2000

Principal Investigator: James Cella

Telephone No.: (518) 387-6173/(518) 387-7342

Short Title of Work: Non-toxic, Self Cleaning Silicone Foul Release Coatings

Reporting Period: January through March 2000

Description of Progress:

Task 1. Design, Synthesis and Testing of Foul Release Paints with Improved Antifouling and Release Properties

Task 1.1 Design, Synthesis and Testing of Foul Release Paints (GE)

Slides coated with GE topcoats were deployed in the Indian River Lagoon in Florida. After 2 months of immersion the slides with barnacles (*Balanus improvisus*) attached were returned to CRD. This species has a fragile shell structure which made the removal of the basal plates for analysis impossible. The animals were removed from the shells and the whole shells along with the slides from which the barnacles were removed were submitted for SEM, XPS, IR analyses, optical microscopy, and optical interference profilometry (Figures 1 and 2).

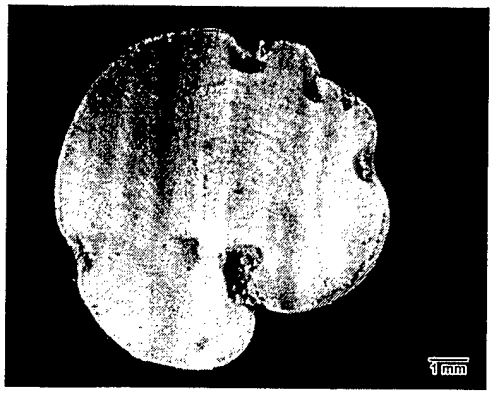

Figure 1. Basal plate of *Balanus improvisus* removed from non-silicone surface

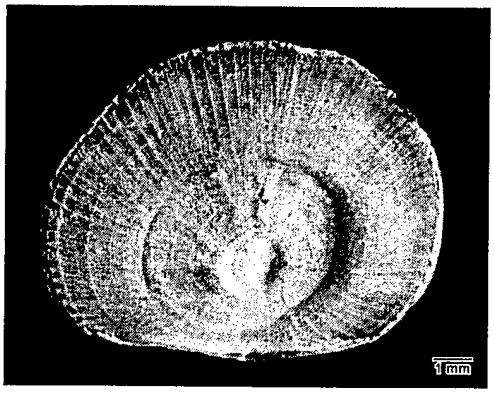

Figure 2. Basal plate of *Balanus improvisus* removed from GE topcoat

Task 1.1.1 Quantitative Foul Release Performance of New Materials (FIT)

Panel Testing
Panels still being tested from the downselect coatings consist of 1, 5, 8, 14, BRA 640, C512-55 series, 20, 21, 22, 23, 24, 25.

Boat power trials
A boat power trial was completed in February 2000.

Task 1.1.2 Field Exposure Testing (Bridger Scientific, Inc.)
Due to the sampling schedule no inspections were done and no new data was collected this quarter.

Task 1.2: Validation Testing (NSWC, University of Hawaii)

S. Hobaica visited the Consumer Power D.E. Karn Plant in Essexville, Michigan on March 28, 2000. The tunnel walls and steel deflecting vanes of the intake bay that serves

both units of the Consumer Power plan had been coated with Exsil 2200 and RTV 11 duplex systems during the week of 18-24 March 1995. There was slime both on the cement and steel surfaces. The foul release coating on the cement was in good condition. The coating had # 6 blisters, a population density of Medium Dense. The blisters were between the topcoat and primer. The fouling rating was 50 according to Naval Ships' Technical Manual, chapter 081, which in this case indicated scattered patches of zebra mussels. The zebra mussels covered approximately 3% of the cement surface according to an extent diagram. The coating could be cleaned easily. The foul release coating on the steel was in good condition. The coating had no blisters, however, it had 10% delamination of the topcoat from the primer on the steel baffles. The fouling rating was 50 according to NSTM 081 which, in this evaluation, indicated random and scattered zebra mussels. These were concentrated in the areas of delamination on the steel baffle. The zebra mussels covered approximately 10% of the steel surface according to an extent diagram. The coating can be cleaned easily by hydroblasting or hand wiping. No corrosion was found on the substrate. Chlorine was used daily to prevent fouling.

USS Paul Foster (DD 964) drydocked at Puget Sound Naval Shipyard in February 2000. The bilge keel panels that were installed in September, 1999 were evaluated using modified fouling ratings (FR) and modified physical deterioration ratings (PDR) for foul release coatings based on modification of ratings in NSTM, chapter 081.

Validation Testing at the University of Hawaii

Fouling on the experimental panels immersed at the University of Hawaii's Ford Island site remained relatively low due to short exposure times. When compared to fouling data from last quarter, we observed lower levels of hydrozoans (AHYD), and slight increases in levels of oysters (MOL) and sediment tubes (MTUB) fouling the panels. Overall Foul Resistance Rating (FRRATE) for all the panels remained greater than 87, and we observed no clear differences in FRRATE between the panels. Physical damage to panels was minimal.

There was significant variation in performance of panels as fouling-release surfaces for both tubeworms and bivalve. For tubeworm adhesion, significantly less force, as judged by mean forces required to remove organisms, was required to remove worms from panels 20 and 21 than panel 22, and the removal force for panel 23 was no different than the required forces of any of the remaining panels. Panels 21 and 23 also performed significantly better than panel 22 for bivalve adhesion. Additionally, there were no differences in mean forces required to remove barnacles from the panels (panel 20, no data; panel 21, mean force 11.2 psi, n=5; panel 22, mean force 18.4 psi, n=3; panel 23, mean force 12.5 psi, n=13). Panel 22 appears to be performing the worst in that it requires significantly more force to remove bivalves and tubeworms compared to the other panels. It should be cautioned, however, that the small sample size (e.g. panel 20) could potentially skew the outcome of these analyses. Longer exposure times will undoubtedly resolve any true differences among panels.

Task 2. Optimize Coating Physical and Application Properties

Task 2.1 Physical Property Optimization (GE)

Evaluation of alternative recoat/ repair systems
The use of the Sigma tiecoat as a repair and recoat system was evaluated over all layers of the GE/Sigma system. The results indicate that the Sigma tiecoat cannot be used as a repair/recoat package for all layers of the GE/Sigma system.

Task 2.1.1 Cleanability of Foul Release Coatings (SUNY Buffalo)

In early February, coating cleanability summary plots were prepared and submitted to General Electric for a DARPA briefing. Summary observations on the data also were included. In early March, General Electric contacted University at Buffalo to announce that the UB subcontract would be reactivated and extended to 31DEC2000. This additional performance period will allow for additional post-exposure analyses of coatings. Panels identified by GE will be shipped to Buffalo from other field sites for surface analyses.

MAIR-IR (multiple-attenuated internal reflection infrared) spectroscopic and comprehensive contact angle analyses of a group of Downselect Set #1 panels received from Bridger Scientific (approx. 270 days exposure) were initiated. MAIR-IR spectroscopic analyses of surface-transferrable silicone residues on post-exposure Downselect Set #2 panels (458 days, freshwater, Medina site) also were performed according to the protocol outlined above. Comprehensive contact angle analyses of the same coatings are planned.

Task 3. Environmental Impact and Toxicological Testing

Task 3.1 Environmental Impact (GE)

Coupons were removed from the immersion tanks and allowed to air dry for 5 days, then they were weighed on 3 consecutive days. The percent difference in weight loss was calculated using the weight at time of testing and the initial weight of the coupon. Downselect 8 panels have lost 3.0% of their initial weight after 339 days immersion in distilled water.

Task 3.2 Toxicological Studies (SPAWAR Systems Center, San Diego)

SPAWAR Systems Center, San Diego has conducted toxicity testing on the latest coatings currently on bilge keel panels and on the small FIT boat.

Task 4. Performance Evaluations

Inspection of Consumers Energy Cooling Water Tunnels in Bay City, MI.
The Navy Duplex systems with GE RTV11 and Exsil 2200 topcoats were applied to portions of the cooling water tunnels in March 1995 during the ESTCP project. At the time of this inspection (March 2000), the coatings were still intact and performing well against zebra mussels. There was minimal amount of coating damage or delamination (approximately 2–3%). The damage and delamination appeared to be a result of biological activity. The slimes and sediment on the coating surface could be removed with light pressure or water spray (Figures 1 and 2). Both coatings had low concentrations of zebra mussels (only attached at surface cavities) which could be easily removed (Figure 3). The results of this inspection are similar to the results seen for the March 1996 inspection. Thus, these coatings are still performing well after 5 years of immersion.

Figure 1. Exsil 2200 covered with slime and sediment and the coating area was easily cleaned with water spray.

Figure 2. RTV11 covered with slime and sediment which could be easily cleaned with water spray.

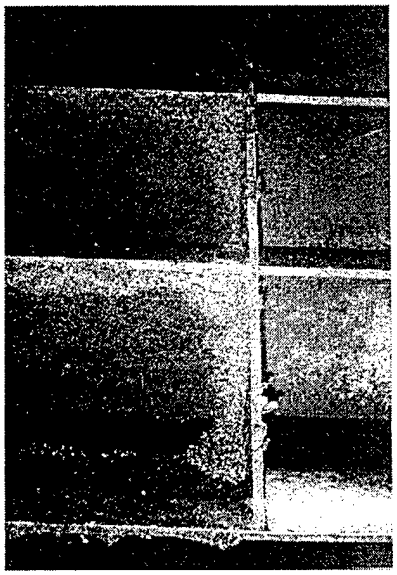

Figure 3. Photo of the steel baffles (left side not coated and the right side coated with RTV11.

Small scale validation application complete

A 19-ft private vessel (McKee craft) was chosen as a test platform for the Sigma/GE fouling release system. The application took place Jan 17-22 in Melbourne, FL. The Sigma/GE silicone fouling release coating was applied by the GE CRD team. The owner and our team at FIT will monitor the coating adhesion and performance over the next few months.

Change in Key Personnel

Karen Poole (NSWC) is in a LWOP status.

Summary of Substantive Information Derived from Special Events

Annual DARPA review was held with Steve Wax in Washington, DC.

Problems Encountered and/or Anticipated

None.

Action Required by the Government

None.

Fiscal Status:	
Project Cost:	$1,916,964
Cost Share:	$ 435,395
Net to ONR/DARPA:	$1,188,576